Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Promoting Spectrum Access for Wireless Microphone Operations	)	GN Docket No. 14-166
	)	
	)	
Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	)	GN Docket No. 12-268
	)	

COMMENTS OF LECTROSONICS, INC.

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Summary

The looming 600 MHz Incentive Auction and repacking of what remains of the UHF TV band will have serious consequences for the wireless microphone industry and wireless microphone users. Users and manufacturers alike are still recovering from the loss of TV channels 52-68 in 2010 when operation of equipment in the 700 MHz band was forbidden subsequent to a previous TV band spectrum auction and repacking. On September 30, 2014, the Commission released a Notice of Proposed Rulemaking which initiates proceedings to address the question of how to accommodate the long term needs of wireless microphone users.[1] Lectrosonics supports the goals of this proceeding including making more efficient use of spectrum and identifying new spectrum allocations for wireless microphone operations. Our industry will face significant challenges in the wake of the Incentive Auction, but we will strive to do all we can to maximize the use of available spectrum while continuing to offer professional users the quality products they need. In this spirit we offer comments based on our long years of experience in the business of designing, manufacturing and marketing wireless microphone products. The comments below address a number of questions raised by the Commission, but we can summarize our key recommendations as follows:

1. We support the creation of a scheme to compensate to some degree wireless microphone users operating on the 600 MHz band who are forced to purchase new equipment as a result of the Incentive Auction and band repacking.
2. Analog wireless microphone technology is useful and must not be deprecated because digital technology is not as mature or cost effective now and may not be for some time to come.
3. Current Part 74 Subpart H power and bandwidth limits are necessary for professional wireless microphones applications and must not be reduced.
4. The Part 74 Subpart H power limit for LPAS operation in the VHF TV band should be increased to conform to the limit for LPAS operation in the UHF TV band.
5. Eligibility for licensed operations in the duplex gap should be expanded to include all entities eligible for Part 74 LPAS licenses.

[1] *Promoting Spectrum Access for Wireless Microphone Operations*, GN Docket No. 14-166, Notice of Proposed Rulemaking, FCC 14-145 (rel. September 20, 2014) ("*Wireless Microphones NPRM*").

6. The ETSI emission mask should not be imposed on unlicensed wireless microphones when a modified version of the existing Part 74 mask will yield the same benefit and avoid compatibility problems between new and old equipment.
7. Any future prohibition on manufacturing or marketing 600 MHz wireless microphone devices must not apply to devices manufactured in the United States solely for export.
8. Eligibility for licensed operations in the 944-952 MHz band should be expanded to include all entities eligible for Part 74 LPAS licenses.
9. The ETSI emission mask should not be imposed on wireless microphones in the 944-952 MHz band when a modified version of the existing Part 74 mask will yield the same benefit and avoid compatibility problems between new and old equipment.
10. The 941-944 MHz and 952-960 MHz bands should be made available for LPAS use on a secondary basis under the same rules governing LPAS operation in the 944-952 MHz band.

Lectrosonics believes that adoption of these recommendations will advance the goals of the proceeding while ensuring that in future wireless microphone manufacturers will be able to provide professional users with the quality products they need for their work.

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COMMENTS OF LECTROSONICS, INC.

Lectrosonics, Inc. respectfully submits these Comments in response to the Commission's *Notice of Proposed Rulemaking* in the above captioned Docket 14-166 proceeding.

I. Introduction

Lectrosonics, Inc. is a manufacturer of professional wireless microphone and IFB (interruptible foldback) cueing and control systems used in TV production, filmmaking, and live sound performances. For over 30 years Lectrosonics has produced equipment operating under Part 74 and Part 15 rules for both licensed and unlicensed uses.

Lectrosonics supports the Commission's goal of accommodating wireless microphone operations after the UHF spectrum reduction consequent to the impending Incentive Auction.[2] The extensive use of wireless microphones in a wide range of industries make it essential to mitigate the effects of the Incentive auction on spectrum availability. To this end Lectrosonics is working to improve our products to allow more intensive use of the available radio spectrum without compromising the performance attributes required by professional users. We also support authorizing wireless microphone operations in certain additional frequency bands as outlined in our comments below.

[2] *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, GN Docket No. 12-268, Report and Order, FCC 14-50 (rel. June 2, 2014) ("*Incentive Auctions R&O*").

II. Diverse Users and Applications Require Reliable & High Quality Wireless Microphones

Lectrosonics wireless microphone products are used for a wide range of applications by a diverse group of professional audio users. Our core market has traditionally been made up of film, video and television production users. These users may employ as few as 6 or 8 channels of wireless microphones on a production, and as many as over 100 channels including for some reality TV productions. Lectrosonics wireless microphone products are most often used in conjunction with other wireless microphone devices and communication tools including 2-way communications, IFB (interruptable foldback), IEM (in-ear monitor), and musical instrument systems. An example is the recent NBA playoff games where over 400 channels of wireless microphones & communication systems were coordinated for each event, with Lectrosonics products representing approximately 10-15% of that total. In that case, most of the Lectrosonics systems were in use by ENG (electronic news gathering) crews. Other sporting events may typically see fewer total channels (48-120, typically) but major events like the Super Bowl will use more than 3,000 frequencies[3] (with Lectrosonics as 5-10% of that total).

Other applications where Lectrosonics wireless microphone products are routinely used include theaters (12-48 channels typically, but potentially up to 60 or more), major news events such as disasters, election campaigns & debates (24 or more channels, mostly used by ENG crews), major press conferences (20 or more channels), touring & performing musical acts (16 or more channels). One example of the latter is the Dixie Chicks, who routinely use in excess of 80 coordinated channels, of which 60 are Lectrosonics units for backline musical instruments and special vocals.

Corporate conference rooms are another application where Lectrosonics wireless microphones are used. Although the channel count is usually relatively small per site (6-24 channels), there are many thousands of such sites throughout the US, including many that are in close proximity to each other in high rise buildings. Finally, broadcast studios rely heavily on wireless microphones, and typically use 24 to 60 or more channels per site, for news, sports, talk show and educational programs.

[3] *Super Bowl RF: 3,500 Frequencies for 10,000 Radios*, TVTechnology magazine (January 13, 2015), http://www.tvtechnology.com/news/0086/super-bowl-rf--frequencies-for--radios/274093.

Approximately 10-15% of the Lectrosonics transmitters sold in the US are the handheld type, used primarily for interviews and also for live vocal performance. 85-90% are body pack type transmitters, located on the talent.

The vast majority of wireless microphones sold by Lectrosonics in recent years employ analog FM transmission. In addition, several hundred channels sold within the past 10 years have used digital modulation, particularly those systems sold to government and corporate clients requiring data encryption for information security purposes. Our new system, the DSW (Digital Secure Wireless) is one such system, and is just beginning to ship in early 2015.

Most of these products operate in the standard UHF TV band between 470-698 MHz. Lectrosonics also manufactures and sells specialized products in small quantities in other frequency bands including wireless microphone systems in the 174-216 MHz part of the VHF TV band, body pack and IFB transmitters in the 944-952 MHz band and a point-to-point wireless system in the 902-928 ISM band.

III. Development of New Wireless Microphone Systems is Likely only on Bands with Favorable Technical, Regulatory and Economic Characteristics

The Commission seeks comment on the factors that manufacturers take into account when considering the development of new devices. Here we describe the factors that have influenced the direction of Lectrosonics' product development in recent years.

Our primary user base consists of licensed, professional Part 74 users. Electronic news gathering (ENG), motion picture production, television studio production and live event applications require robust, interference free RF performance to carry high quality audio. New wireless microphone products are developed and marketed only if there is a reasonable chance that they can satisfy customer expectations for operating range, audio quality, reliability and price. The qualities of the frequency band used determine the degree to which these expectations can be met in a practical system.

A. Operating range considerations

Operating range is a key factor for many applications, especially ENG and motion picture production. For example, during the Candlestick Park earthquake in San Francisco, local news gathering crews were prohibited from dragging cables into damaged areas because they would interfere with the movement of first responders. Crews equipped with wireless microphones however could send a reporter onto the scene and get accurate information while the camera

remained outside the emergency area. The availability of wireless microphones with the necessary range (50m or greater) made this possible.

In motion picture and television production, the “long shot” with live dialog is a situation that cannot be handled with boom microphones or after the fact ADR (dialogue replacement). Scenes including moving vehicles or animals (horses for example), complex crowd shots and large outdoor scenes all require wireless microphones with good range.

In sport, the very nature of a highly mobile athlete on a large field of play precludes the use of anything except a well powered transmitter. All major league sports now feature live audio from the field through transmitters on the players to enhance the enjoyment of the game by the viewers. Here again wireless microphone systems with good range are needed to meet the demands of a professional application.

The maximum allowable transmitter power set by Part 74 rules is a key factor affecting operating range in practical applications, but not the only one. Factors such as antenna efficiency, receiver sensitivity and propagation characteristics also come into play in defining the maximum range of a wireless microphone system. These factors are determined by the physical properties of the frequency band used. Together, these physical and regulatory considerations make the choice of frequency band critical when designing a wireless microphone system with a requirement for maximum possible operating range.

For these reasons Lectrosonics favors the UHF band for new product development because we can realize the best operating range for practical systems on this band. Here we can take advantage of the 250 mW power limit and favorable RF propagation characteristics of the band. To provide licensed users with the flexibility they need to move between applications with differing operating range requirements, many of our transmitters offer a variable output power feature, user selectable for 50, 100 or 250 mW. While most users find power levels of 50 or 100 mW adequate to meet range requirements, for some applications the full 250 mW power level is needed. With proper frequency coordination there is no detrimental impact on other users in the immediate area at any of these levels.

B. Licensing considerations

The choice of band also affects the likelihood that the wireless microphone system will be subject to interference, which reduces effective operating range or completely disrupts the use of the system. In particular, ISM bands such as the 915 MHz and 2.4 GHz bands are

problematic. In our experience wireless microphones operating in these bands can be subject to severe and uncontrollable interference from other devices on the band. For example, our IEM system operating on the 915 MHz Part 15 band sometimes encounters interference from devices such as lighting control systems which reduces operating range and from which there is no protection under the Part 15 rules. For these reasons we have concentrated professional wireless microphone development effort on the UHF TV bands, where licensed users are afforded interference protection by Part 74 rules, and which professional users find more predictable and reliable than Part 15 operation on the ISM bands.

C. Audio quality considerations

Here the requirements of professional users are strict; wireless microphones used in motion picture production, live musical or theatrical events and television production applications must deliver audio of the best possible quality. Key requirements for professional users are high dynamic range (103 dBA or better), a wide audio band frequency response (35 Hz to 20 kHz), and freedom from noise and other artifacts of the radio link. In this regard the occupied bandwidth limit of the chosen band has a large impact. In our FM wireless microphone systems the dynamic range and signal to noise ratio of the audio signal is constrained by this limit; in our digital wireless microphone systems the audio frequency response is also constrained by it. The technical rules for the UHF TV band permits a 200 kHz occupied bandwidth, which is sufficient to support the audio quality expected of professional wireless microphones. This is another reason we find this band attractive for development of new products.

D. Band size considerations

Prior to 1987, Lectrosonics developed Part 74 LPAS devices for the 174-216 MHz VHF band. These products, while functional, had limitations related to antenna size and efficiency, maximum allowed power, and occupied bandwidth (under the Part 74 rules in effect at the time). When, in 1987, the Commission opened up the 470-806 MHz UHF band for wireless microphones on unused channels, the technical advantages offered by this band caused an immediate demand for products for use there. These technical advantages included higher power levels, better RF propagation characteristics and more practical antenna size.

The fact that the UHF TV band was large and contiguous in frequency (excepting TV channel 37), meant that applications with high channel counts could be supported as there was

sufficient empty spectrum available in all TV markets. This lead to a concentration of market demand in the UHF band and caused us to focus development efforts on UHF products to satisfy it. The large unit volumes produced in this single band allowed economies of scale in manufacturing which tended to keep prices down and allowed us to compete effectively in the market.

Another attractive aspect of the UHF band is that it is generally available for wireless microphone operations in markets outside the United States. This permits us to offer modified versions of our UHF product adapted to export markets such as the European Union, Canada, Brazil, Japan, and many others, further boosting the volumes produced for this band.

After the 700 MHz auction however, increased UHF band congestion in some areas led to revival of our interest in alternate bands in the United States, so we developed systems for operation in the Part 15 915 MHz band. This was a smaller band with limited market demand from professional users, so development and tooling costs had to be amortized over low unit volumes, making it impossible to achieve the same economies of scale as for our UHF products.

Lectrosonics welcomes the Commission's effort to identify additional spectrum for wireless microphone use. However, our past experience leads us to believe that new frequency allocations which are too small, or which offer only limited access would not be enticing for users or manufacturers. If wireless microphone operation is scattered over many isolated bands of frequencies with differing technical requirements, product planning will become very difficult for manufacturers. For a given band there must be the prospect of market demand sufficient to justify development costs, and to assure reasonable economies of scale to keep prices at reasonable levels.

Product testing and certification costs are worth noting in particular. Each new wireless microphone frequency band will require products specialized for those frequencies and technical rules. Product testing and certification costs will be incurred for each, with the burden increasing if the number of models with unique compliance test requirements grows faster than total unit sales as a result of the dispersion of wireless microphone channels over multiple bands.

IV. We Expect a Time to Market of 2 to 3 Years for Newly Developed Wireless Microphones in New Bands

In terms of time to market for new products aimed at new areas of the spectrum or revised rules, in general the closer to existing spectrum used for these purposes, the shorter the

time to market. For instance, revising the rules for the 174-216 MHz VHF band to closer align with Part 74 rules for UHF wireless microphones would likely yield products quickly, since the VHF band is already in use for this purpose and is well understood by wireless microphone manufacturers. Similarly, expanding the 944-952 MHz band to 941-960 MHz would yield new products quickly since we are already making products in this band.

For other bands not currently being used, time to market with new products would be longer, from a minimum of 2 years upwards to 3 or 4 years depending on the technological and regulatory challenges involved. In general, the higher the frequency range, the more time is needed because of greater complexity of design as frequency increases. Radio frequency design techniques and components quite different from those used in the VHF and UHF TV bands are needed for higher frequency bands such as the 2.4 GHz and 5 GHz ISM bands.

Since significant development and testing will be required to make reliable, professional grade products that our users trust for critical applications, the sooner we have a roadmap for new frequency allocations, the sooner we can begin investing in earnest in this process.

V. Transitioning Wireless Microphone Users from the 600 MHz Band in a Timely Manner Will Require a Mix of Outreach and Incentives

With the 700 MHz transition a few years ago as an example, our industry and we as a manufacturer face significant challenges with communication and policymaking in regards to a further shrinking UHF availability. As for communication, we will again plan to work closely with trade media outlets to inform professional users of the timeline and necessary steps for vacating or working around the new spectrum restrictions. Social Media now plays a much larger role and can also be helpful for reaching users. Timely and careful dealer and distributor notices will also be employed.

In terms of aiding users in the transition, we plan to offer the owners of Lectrosonics UHF equipment operating in the 600 MHz band the option to have these units modified at a reasonable cost in order to conform to the new rules. The cost to the user is approximately 1/3 the price for purchasing said equipment new so we hope the policy acts as an incentive to users to move out of the 600 MHz band in a timely manner. Although a better option than outright abandonment of serviceable equipment, the cost can be a significant burden to a user with many channels of wireless requiring modification or replacement.

Since a significant portion of our user base is Part 74 licensed, we hope to see some sort of compensation for these users who will need to modify or abandon their 600 MHz band equipment for new despite the fact that it may have been purchased relatively recently (during or after the 700 MHz transition) and is otherwise perfectly serviceable.

We support Sennheiser in their effort to press for compensation for these displaced users.[4] This has recently been done in countries like Japan and the United Kingdom where spectrum refarming actions have forced users to purchase new equipment.[5] Such a scheme would be also helpful in ensuring the timely migration of eligible equipment owners.

In terms of a transition timeline, we feel that the currently proposed plan (39 months following spectrum auction) is reasonable, although the more time manufacturers and users have for communication and equipment trade-in or modification the better. In addition, the longer serviceable life these users get from their current (post 700 MHz auction) equipment, the less need for displacement compensation.

Furthermore, we request that additional frequency bands for wireless microphone use be finalized at or about the same time the auctions conclude, giving manufacturers adequate time for development, testing and marketing of new products utilizing these bands.

VI. A Mix of Analog and Digital Technologies is Needed to Support the Wide Range of Wireless Microphone Applications in the TV Bands

Lectrosonics has been implementing both analog and digital wireless microphone technologies for many years. We've become familiar with the characteristics of both technologies and find that each has strengths and weaknesses, and that there are applications for which one or the other are best suited. Consequently we continue to develop, manufacture and market systems of both types, including hybrid products with digital audio processing combined with a conventional FM radio link.[6]

Analog technology remains practical and attractive for many applications. A traditional analog FM wireless microphone system is relatively simple to design without the complex parts, high speed clocks and specialized firmware required in a digital system. This simplicity is reflected in lower parts costs, less power consumption and less difficulty in achieving

[4] See Sennheiser Petition for Reconsideration (GN Docket No. 12-268) at 10-15 (Sep. 15, 2014).
[5] Licenced wireless microphone users in the United Kingdom who were displaced from repurposed spectrum received partial compensation. See http://stakeholders.ofcom.org.uk/consultations/pmse_funding/statement/.
[6] Thomas, David B. "Signal-predictive audio transmission system", US Patent No. 7,225,135. 29 May 2007.

compliance with regulatory standards governing unwanted emissions. Analog systems naturally exhibit very low audio latency which makes them especially suited for applications such as live sound where little or no audio delay can be tolerated. The "capture effect" exhibited by FM receivers provides significant co-channel interference rejection.[7] The result is a reliable and affordable system capable of excellent audio performance.

The advent of digital technology is a recent development in the wireless microphone industry, and it may take years for it to evolve to the point where it can replace the incumbent FM technology in all applications. Lectrosonics is especially concerned about the needs of professional users who rely on the performance available today in FM systems for demanding applications where digital techniques have no long history of use and may be subject to unexpected problems. Nonetheless we are optimistic about the potential for digital technology, especially in a future in which less spectrum is available for wireless microphones. We have developed and brought to market several digital wireless microphone systems and will continue to do so, taking advantage of technological advances as they come. We recognize however that our proven analog products will remain in use and in demand for a long time to come while our digital products gradually evolve to meet the needs and earn the trust of professional users.

For these reasons Lectrosonics believes that both analog and digital technologies must remain available in the future to satisfy the full range of wireless microphones applications. We urge the Commission not to deprecate analog technology.

VII. Current Part 74 Subpart H Power and Bandwidth Limits Enable Professional Applications and Must Not Be Reduced

When designing a wireless microphone system we face a difficult balancing act between cost, performance and power consumption. Our chief markets are those requiring very high production values, such as film making, television production and live events. The audio requirements for these applications are full bandwidth (50-20000 Hz), low distortion (less than 0.5% THD) and high dynamic range (103 dBA or better). The system must offer sufficient dropout-free operating range (up to 100 m) and good battery life. Low audio latency is necessary in applications such as live events.

[7] We observe typical capture ratios of 2 dB or less for a 30 dB suppression of the unwanted signal in our FM wireless microphone systems.

We have been able to offer both analog and digital designs that meet these requirements, under the current FCC Part 74 Subpart H rules. These accommodate professional wireless microphone uses in two important ways:

1. The ability of licensed users to use power levels of up to 250 mW has enabled applications where working range is critical.

2. The 200 kHz channel bandwidth permits the high quality audio characteristics needed for professional applications.

It is sometimes suggested that the bandwidth of wireless microphone signals be reduced as a way to increase spectrum usage efficiency. Unfortunately any reduction of the current 200 kHz bandwidth limit will result in harm to the primary purpose of wireless microphones in professional applications, which is delivering very high quality audio signals.

One way to limit signal bandwidth is to compress the audio information prior to transmission, to reduce the rate of information transfer required. Unfortunately the effect of any compression algorithm is to degrade the audio signal to some degree. These degradations can include reduced audio frequency bandwidth, higher distortion, lower dynamic range, increased latency (delay) and the introduction of audio artifacts. Professional users expect a lossless or "transparent" audio transport, with no loss of audio fidelity in the process.

With digital systems, another way to limit signal bandwidth is to use higher order modulation schemes, so that the RF link conveys information at a higher rate. For example going from QPSK to 8PSK increases the amount of data sent in the same RF bandwidth by 50%. It is possible to keep the data rate the same and simply decrease the occupied bandwidth by 33% in theory. But this comes at a price. When using higher order modulation the final amplifier stages of a transmitter needs to be more linear then if a signal of lower modulation complexity is passed through them. This requires higher power circuitry that will draw more current, hence reducing battery life in the case of handheld or body worn wireless microphones. An alternative is to employ active linearization techniques such as Cartesian feedback (described below), but it seems unlikely to us that such techniques can be realized in a practical way in battery powered wireless microphone transmitters in the near future.

Also, the use of higher order modulation schemes generally entails an increase in the signal-to-noise ratio (SNR) required at the receiver, so that operating range is reduced if transmitter power and receiver sensitivity are held constant. Wireless microphone receiver

sensitivity is ultimately limited by the ambient noise floor at the frequency of operation, but in practice is also limited by factors such as size, cost and performance of available technology. Receiver sensitivity is a major factor in determining the range of UHF wireless microphone systems, and over the years we have benefited from advances in filtering and low noise amplifier (LNA) technologies to improve receiver performance. We envision further technical progress in this area, but size and power consumption considerations will determine the degree to which they are practical, especially in the case of small camera mounted wireless microphone receivers.

However, it is not the allowed bandwidth, but the phenomenon of intermodulation interference which is the factor limiting spectrum efficiency in most applications. Together with an improved emission mask, improvements in the intermodulation interference characteristics of wireless microphone transmitters are needed, not a reduction in occupied bandwidth.

For these reasons Lectrosonics urges the Commission not to change the current Part 74 Subpart H power and bandwidth limits in the interest of maintaining the level of performance that professional wireless microphone users have come to rely on.

VIII. Transmitter Generated IMD Interference is the Limiting Factor in the Spectrum Efficiency of Multi-channel Wireless Microphone Applications

Regardless of signal bandwidth, the ability to pack more microphones into a given amount of spectrum is limited by the effects of intermodulation (IMD) interference. When multiple wireless microphone transmitters are operating in the same vicinity, intermodulation products are generated in the final RF amplifier stages of the transmitters by a mixing action. The resulting spurious signals are generated on multiple frequencies and when radiated can cause interference to receivers on another channel. This effect increases as the distance between transmitters is reduced and limits the number of transmitters that can be operated concurrently in a common area. The severity of the problem also depends on the degree of nonlinearity of the transmitter RF amplifiers. The effect diminishes greatly if these RF amplifier stages are designed to be very linear, as is the case with certain digital systems whose modulation scheme cannot tolerate nonlinearities in amplification. On the other hand, traditional FM transmitters

designed with RF amplifiers operating in Class C service are highly nonlinear so IMD interference effects can be more pronounced if not mitigated somehow.[8]

Transmitter generated IMD can be reduced significantly by using ferrite isolators between the final RF amplifier stage and the antenna. This is a directional device which allows power to flow from the amplifier to the antenna to be radiated, but greatly attenuates power flowing in the opposite direction and thus the level of IMD generated in the transmitter. This is the technique used by Lectrosonics in our UHF "digital hybrid" FM wireless microphone transmitters and our experience shows that it can be very effective. It suffers from the disadvantage that the tuning range of the transmitter is limited by the frequency range of the circular isolator component, which is typically less than 30 MHz. This limitation is in conflict with market demand for systems which tune over ever greater frequency ranges to maximize the possibility of finding open channels in increasingly crowded TV band spectrum. We note that this frequency range limitation would not be a problem for operations in the 941-960 MHz UHF band (only19 Mhz wide) which may in future be more accessible for wireless microphone use.

Active linearization techniques such as Cartesian feedback applied to the final power amplifier (PA) stage of digital transmitters are another possibility. These work by sampling the RF output from the final PA, converting it to in-phase (I) and quadrature (Q) components, then feeding these signals back to the input of the modulator to be mixed with the I and Q signals which drive it. By careful control of the amplitude and phase of the feedback signal some amount of pre-distortion can be applied to the PA to cancel distortion generated by the PA, lowering the occupied bandwidth of the RF signal. Such techniques can be helpful but come at a price of greater design complexity and higher power consumption. Implementation will prove challenging for wireless microphone transmitters, which are usually battery powered and compact in size, and expected to operate over a wide frequency range. To date we have been unable to realize a practical version of this technique and don't foresee one in the near future suitable for our wireless microphone transmitters.

One simple, direct way to reduce IMD generation in transmitters is to modify the RF amplifier operating point to improve its linearity by increasing current consumption.[9] The

[8] Frequency modulation schemes can be implemented using RF amplifiers designed for Class C operation, which makes them much more power efficient than linear amplifiers. This makes FM a popular modulation choice for wireless microphone systems with small battery powered transmitters.

benefit this confers must be weighed against the reduction of battery life and increase in heat buildup that results.

Another approach is simply to reduce transmitter power when IMD problems arise because of the proximity of one transmitter to another. This can be effective but the resulting reduction of operating range will not be acceptable in many applications. It is not difficult to incorporate reduced power options in transmitter designs that could be used in short range applications to increase the number of wireless microphone channels that can be operated concurrently.

Lectrosonics is actively seeking new solutions to the IMD generation problem. The market is demanding improvements in this area and we believe that other manufacturers will respond to this demand as well.

IX. Power Limits for LPAS Operations in the VHF Band Should Conform to Those Applicable for the UHF Band to Promote Greater Use of the VHF Band

Lectrosonics has manufactured wireless microphone systems which operate in the VHF band on TV channels 7-13 for many years. However, certain disadvantages pertaining to VHF operation have made these products less effective than UHF systems and as a result they currently enjoy little market acceptance.

a. VHF band frequencies require antenna dimensions that are inconvenient for body worn wireless microphone equipment. Wireless microphone antennas generally need to be at least ¼ wavelength long to work well. On the VHF frequencies this translates to lengths on the order of 15 inches (0.375 m at 200 MHz). This is impractically long for a whip antenna on body worn transmitters, but the consequence of physically shortening the antenna is reduced radiation efficiency.[10] A typical workaround is to use the conductive shield of the attached microphone cable as an antenna but again radiation efficiency can be quite poor, particularly when the cable must be dressed close to the body of the wearer and RF absorption increases. In contrast, ¼ wavelength antennas for UHF operation are much more practical, with lengths on the order of 6 inches (e.g. 0.15 m at 500 MHz). These shorter antennas are easier to position effectively and much greater radiation efficiency is realized in most applications.

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[9] For example an FM transmitter can be designed with an RF amplifier operating in Class A instead of Class C. The power efficiency of the amplifier stage will fall steeply however, from perhaps 60 % to 30% or less.

[10] There are ways to design whip antennas which are physically shorter than ¼ wavelength on a particular frequency band but behave electrically like ¼ wavelength radiators in most respects. Unfortunately radiation efficiency suffers anyway so shortened antennas can't ever be as efficient as the full size antennas found on UHF equipment.

b. The VHF band power limit for LPAS devices is only 50 mW whereas on the UHF band it is 250 mW.

These factors combine to make VHF wireless microphone systems less popular than UHF systems; Lectrosonics has ceased to manufacture all but a few models as a result. VHF systems are often perceived as being deficient in terms of working range, particularly when compared to the 100 mW or 250 mW UHF systems operated in professional applications where good range is a paramount consideration.

Lectrosonics believes that the VHF band can be better utilized if the power limit for LPAS operation were increased to 250 mW. This would help to compensate for antenna efficiency deficits and increase the performance of VHF wireless microphone systems enough to make them a viable alternative to UHF systems for many applications. We also foresee entirely new applications made possible by this change.

In particular, IFB ("interruptable foldback") cueing and control systems could be made practical in the VHF band if the power limit was increased, releasing UHF spectrum for other wireless microphone operations. IFB systems consist of a transmitter at a fixed location which broadcasts voice cueing signals from a director to multiple receivers worn by crew members on a sound stage or other theatrical, film or TV production location. IFB systems for the UHF band can operate at power levels of up to 250 mW to ensure adequate coverage of the locations they serve and they have enjoyed wide adoption in many industries. However, the 50 mW power limit in the VHF band has made development of an IFB system with a comparable working range difficult and to date we have not been able to offer such a system. If, however, the VHF band power limit were raised to 250 mW we believe that a VHF IFB system with sufficient range could be realized, making the band useful for what is very common LPAS application.

Considering the looming reduction in UHF TV band spectrum available for wireless microphone and IFB applications, every effort should be made to make the VHF TV band a viable alternative for operations that will be displaced. We believe that an increased power limit in the VHF band, conforming to that in the UHF band, is an important step in this direction and we recommend that the Commission make this change.

Lectrosonics recognizes that an increase in the power limit will require reconsideration of the co-channel separation distance to prevent interference to VHF TV stations. We recommend implementation of a tiered separation requirement, where the distance varies with the power

level. In this scheme wireless microphones operating at or below 50 mW should comply with the 4 kilometer distance, with the distance increasing with power above this point.

X. There is No Need to Impose the ETSI Emission Masks on Unlicensed Wireless Microphones when a Modified Version of the Existing Part 74 Subpart H Mask Will Yield the Same Benefit while Avoiding Compatibility Problems between Old and New Equipment

Lectrosonics manufactures wireless microphone products for the US, Canadian and European Union (EU) markets. Many of our products are used for unlicensed operation pursuant to the Commission's limited waiver and certain Part 15 rules[11], and here we address the Commission's proposal to apply the ETSI emission masks to analog and digital wireless microphone systems in unlicensed operations.

A. Analog systems

We are familiar with the ETSI EN 300 422-1 analog emission mask because we design our products destined for the EU market to conform to this mask.[12] However, the definition of this mask makes it necessary for these products to differ from those designed for the US and Canadian markets, which comply with the FCC Part 74 subpart H and Industry Canada RSS-123 technical rules for LPAS devices. In particular, the maximum frequency deviation of the EU products must be reduced to contain the signal spectrum within the limits of the ETSI mask.[13] This has two significant effects:

a. The audio dynamic range is scaled downward with the reduction in frequency deviation, shifting level thresholds important to the audio processing algorithms.[14]

b. The deviation of the supersonic pilot tone feature is reduced.[15]

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[11] *TV Bands Wireless Microphones R&O and Further Notice*, 25 FCC Rcd at 676-687 ¶ 70-91.

[12] ETSI EN 300 422-1, *Electromagnetic compatibility and Radio spectrum matters (ERM); Wireless microphones in the 25 MHz to 3 GHz range; Part 1: Technical characteristics and methods of measurement*. Available at www.etsi.org.

[13] The maximum carrier frequency deviation of our EU FM transmitter models is reduced to 60% of the maximum deviation of our US/Canada models, a difference of 4.4 dB. This ensures that the signal conforms to the ETSI mask with plenty of margin under the method of measurement given in EN 300 422-1 §8.3 where the modulating signal is shaped white noise.

[14] In frequency modulation systems, the carrier frequency deviation is a function of the amplitude of the modulating audio signal.

[15] Supersonic pilot tones are inserted in the transmitted signal to prevent the receiver from responding to signals other than those generated by its matching transmitter (each channel uses a unique pilot tone frequency in the range 25-32 kHz). The frequency deviation of these supersonic tones in the EU system models falls to ±3 kHz (from ±5 kHz) to maintain compliance with the ETSI emission mask.

The change is small but necessary to conform to the shape of the ETSI mask in the immediate vicinity of the carrier frequency (between the -60 dBc points) where our current Part 74 compliant signal infringes slightly, by 2-3 dB. Nonetheless, because of the mismatch in dynamic range, thresholds pertaining to audio processing, and pilot tone levels, our FM wireless microphone systems designed for conformity with the ETSI mask are *incompatible* with those previously designed to conform to Part 74 technical rules. Based on this experience we know that adoption of the ETSI emission mask in future FCC technical rules will force a breaking change in our designs for the US market, rendering legacy models incapable of interoperating with new models.

We understand why the ETSI emission mask was suggested. The attractive feature of this mask is the strict control of in-band, out-of-channel emissions which should improve efficiency of spectrum use by allowing closer spacing between signals in multichannel applications. However, the compatibility problems described above mean that we cannot support adopting this mask even though we agree with the purpose of the Commission's proposal. Note that our current Part 74 signal has no difficulty complying with the ETSI mask in the region *outside* the immediate vicinity of the carrier (beyond the -80 dBc points).

Therefore, to resolve this difficulty we propose an alternative emission mask for wireless microphones; one which is a stricter version of the existing generic mask given in FCC Part 74 Subpart H.[16] This mask enforces in-band, out-of-channel limits similar to those of the ETSI mask, with comparable spectrum efficiency benefits, while also preserving compatibility with our systems certified under current FCC Part 74 rules. It is defined as follows:

> The mean power of emissions shall be attenuated below the mean output power of the transmitter in accordance with the following schedule:
>
> (i) On any frequency removed from the operating frequency by more than 50 percent up to and including 75 percent of the authorized bandwidth: at least 30 dB;
>
> (ii) On any frequency removed from the operating frequency by more than 75 percent up to and including 100 percent of the authorized bandwidth: at least 55 dB;
>
> (iii) On any frequency removed from the operating frequency by more than 100 percent of the authorized bandwidth and up to and including the frequencies removed from the operating frequency by 1 MHz: at least 80 dB;
>
> (iv) On any frequency removed from the operating frequency by more than 1 MHz up to the limit of the authorized band: at least 80+10log10 (mean output power in watts) dB;

[16] 47 C.F.R. § 74.852(e)(6).

(v) On any frequency outside the authorized band: at least, 55+10 log10 (mean output power, in watts) dB.

This proposed emission mask (thick red line) is depicted in Figure 1, superimposed on the ETSI mask (thin black line) for analog transmitters given in EN 300 422-1.

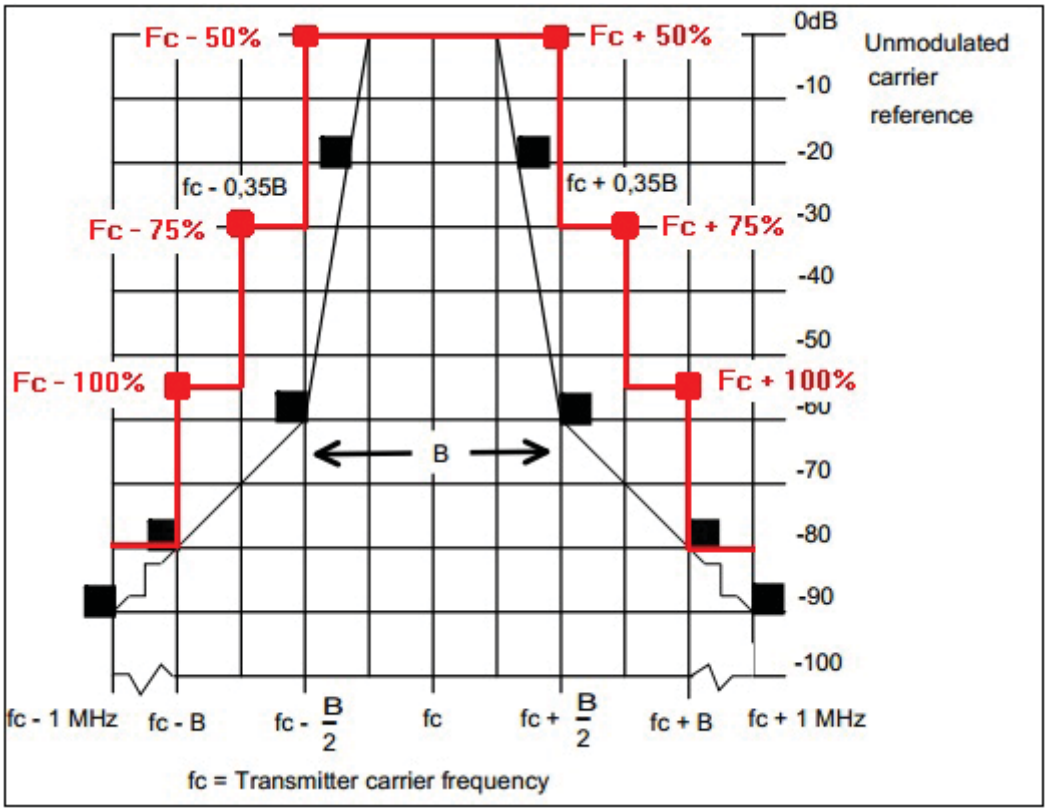

Figure 1.

Bandwidth parameter *B* in this context is the maximum operating bandwidth of 200 kHz in Part 74 Subpart H §74.861 (5). Note that the proposed mask coincides with the ETSI mask at the $F_c \pm B$ frequency points where the limit is -80 dBc for both. Outside the $F_c \pm 1$ MHz points but within the authorized band the required attenuation of 80 + 10log10(Po) offers protection comparable to the ETSI mask. The proposed out-of-band limit is aligned with the stricter Industry Canada limit found in IC RSS-123 which requires 12 dB more attenuation than the current FCC rule.[17]

In summary, Lectrosonics is concerned that adoption of the ETSI emission mask for unlicensed wireless microphone operations will force a breaking change in our designs for the

[17] IC RSS-123 Issue 2, *Licensed Low-Power Radio Apparatus*. §5.5.1 Available at www.ic.gc.ca.

US market, rendering legacy models incapable of interoperation with new models. Such a change will place a significant burden on users with inventories of legacy equipment who find themselves with equipment that is deprecated and are unable to purchase replacement units. Therefore we urge the Commission to adopt the wireless microphone emission mask proposed here rather than the ETSI mask. Doing so will yield substantially the same spectrum efficiency benefits while avoiding the disruptive effects of the compatibility break between our old and new wireless microphone models which will result if the ETSI mask is used.

B. Digital systems

Recently developed Lectrosonics digital wireless microphone systems are designed to comply with the ETSI emission mask for digital systems. However, we propose that in the interest of simplicity that the Commission specify a single emission mask for all wireless microphones, whether digital or analog, i.e. the mask proposed above for analog systems.

XI. Eligibility for Licensed Operations in the Duplex Gap should be Expanded

The Commission asks if eligibility for wireless microphones in the duplex gap should be expanded to include all entities eligible for Part 74 LPAS licenses. Lectrosonics believes the answer to be unequivocally yes. Many Part 74 licensed location sound mixers and television production mixers currently own equipment that can operate in the duplex gaps. They rarely if ever operate in the same locations as broadcaster or ENG crews but if they do, operations are frequency coordinated as a matter of routine. Allowing all Part 74 operators access to the duplex gap will help alleviate the loss of other portions of the 600 MHz band and avoid the complete obsolescence of current equipment capable of operating there.

XII. The Prohibition on Manufacture or Marketing of 600 MHz Wireless Microphone Devices Must Not Apply to Devices Manufactured in the United States Solely for Export

Lectrosonics manufactures and markets wireless microphone equipment for export, specifically made to conform to regulations in force in those markets. Many of these devices are not FCC type accepted because they operate in the prohibited 700 MHz band, which is still available in many export markets. Because all of our manufacturing takes place in the United States it is imperative that we be able to continue with production of such devices after the 600 MHz band prohibition takes effect. Export products account for a large fraction of our total sales, helping to support our workforce of over 160 persons employed here in the United States.

Therefore we urge the Commission to stipulate that the ban on manufacturing 600 MHz devices does not apply to product manufactured in the United States for export.

XIII. The 944-952 MHz Band has Proven Useful Already and Eligibility for Licensed LPAS Operation under Part 74 rules in this Band should be Expanded

Lectrosonics currently offers several analog wireless microphone and IFB products in the 944-952 MHz band. The operation of LPAS devices in this band is currently limited to broadcasters only, not all licensed Part 74 users and for this reason our policy is to restrict sales of our products on this band to broadcast licensees only.[18] This band is considered a safe haven for operations in critical applications where the interference cannot be tolerated. Operation requires careful frequency coordination to avoid conflicts with other uses such as STL (Studio Transmitter Link) stations, but the additional spectrum made available here has proven quite useful for licensed professional users. Because this band has favorable propagation properties similar to the UHF TV band, it is useful for outdoor applications where long range is necessary. Indoor applications are also found. One popular use of this spectrum is for IFB (interruptible foldback) systems used for cueing and control of production activities where reliability of communication is critical. From a manufacturing point of view the design of products for the 944-952 band is simplified by the band's close proximity in frequency to the UHF TV bands; design work and component sourcing already done for the UHF band can be leveraged, reducing development costs and time to market. Another favorable factor is that devices for this band are governed by the same the Part 74 Subpart H technical rules as those for the TV bands.

The Commission suggests that the ETSI standards be adopted for analog and digital wireless microphone systems in this band. Lectrosonics agrees with the goal of increasing spectrum efficiency, but we oppose the adoption of the ETSI emission mask for analog systems. Doing so will force a breaking change in our designs for the US market, rendering legacy models incapable of interoperation with new models. Such a change will place a significant burden on users with inventories of legacy equipment who find themselves with equipment that is deprecated and are unable to purchase replacement units. Therefore we urge the Commission to adopt the wireless microphone emission mask proposed in these comments rather than the ETSI mask.[19] Doing so will yield substantially the same spectrum efficiency benefits while avoiding

[18] 47 C.F.R. § 74.832(c)-(d).
[19] See Part X for details on the proposed emission mask.

the disruptive effects of the compatibility break between our old and new wireless microphone models which will result if the ETSI mask is used.

The Commission also suggests that eligibility for licensed LPAS operations be expanded to include the same additional entities that are currently eligible to operate on a licensed basis in the TV bands. Lectrosonics agrees with this proposal. This would allow motion picture and television production location sound mixers access to additional spectrum for content development in a band with properties suitable for their operations. Professional users in these industries will need every bit of useful spectrum that can be found to replace the loss of the prime 600 MHz band for their applications.

XIV. The 941-944 MHz and 952-960 MHz Bands Should be Made Available for Wireless Microphone Operation on a Secondary Basis Under the Rules Applicable for LPAS Operations in the 944-952 MHz Band

Lectrosonics recommends that the 941-944 MHz and 952-960 MHz bands should be made available for LPAS operation on a secondary basis by licensed users as suggested by the Commission. The result, access to parts of an additional 11 MHz of desirable UHF spectrum, will be very beneficial to professional users. To maximize the benefit we urge that the same technical rules be applied for these new secondary use allocations as for those in the 944-952 MHz band. Doing so will assure better understanding by operators and simplify the design of products aimed at these bands. Also, given that we and other manufacturers have already developed products for the 944-952 MHz band, wireless microphone products supporting the new spectrum can be brought to market relatively quickly, with only a small amount of modification to the 944-952 MHz designs needed. We recommend that manufacturers be able to certificate new devices under the same rules and procedures that apply to devices in the 944-952 MHz band.

We recognize that current situation of these bands is complex, with a mix of different services operating under different technical rules. However, on first analysis it seems that the disposition of incumbents in a locality is static in both frequency and location so LPAS users should be able to coordinate frequencies with a high degree of confidence. As the Commission notes, the relatively low power at which LPAS devices operate makes it highly unlikely that they would cause harmful interference to the high powered incumbent services. We believe that it will be sufficient to rely on frequency coordination by licensed users in these bands to prevent

conflicts, just as these users already coordinate operations on the 944-952 MHz band to prevent conflicts with STL operations. We will study the matter further to better understand the frequency coordination challenges involved, in particular the means by which LPAS users can determine which frequencies in the band are safe to use in their area of operation.

Respectfully submitted,

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